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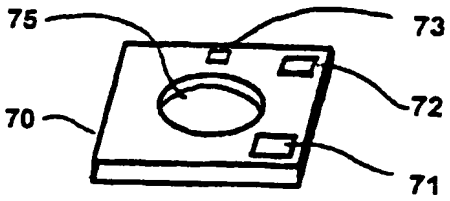
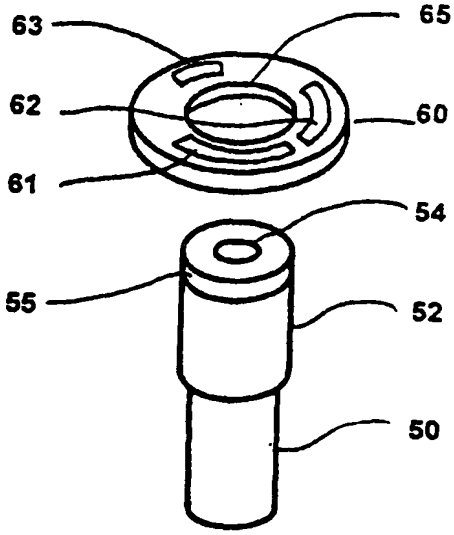
(54) Title: PHOTOGRAMMETRY TARGETS





(57) Abstract: This invention relates to targets for use in photogrammetry and provides a set of photogrammetry targets comprising a first portion and a plurality of interchangeable second portions, wherein the first portion comprises a first connector for connection to a workpiece and wherein each of the plurality of interchangeable second portions carries a respective different visual identifier on an outer surface thereof and each comprises a second connector for connection to the first portion. The invention also extends to a method of applying a photogrammetry target to a workpiece, comprising the steps of attaching a first target portion to the workpiece at a predetermined position thereon and attaching a second target portion carrying a visual identifier on a surface thereof tot he first target portion.

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PHOTOGRAMMETRY TARGETS

This invention relates to targets for use in photogrammetry.

In computer aided manufacturing and similar techniques, it is often desired to know the exact position of an article, in the co-ordinate system of a reference system (for example the frame of reference of the factory) to enable the article to be machined or manipulated by a computer-guided tool.

In order to achieve this, it is known to provide photogrammetry targets. Such targets comprise reflective components which can be positioned at known positions on the object to be processed. They may be so-called "simple" targets, or "coded" targets carrying coded information, in which case each target of the set carries a different identifiable code. Each is accurately manufactured to enable it to be precisely located on the object.

In use, several different camera positions are used to image the object from different angles. Each target will fall within the field of view of more than one camera. By measuring the position within the field of view of the target of (and hence its direction from) each of the cameras, the position of the target in space can be calculated, in the common frame of reference of the cameras.

From the measurements from all of the targets, the positioning necessary to process the object (e.g. by manipulating the object, or by drilling a hole at a precise location on the object) can be derived.

A number of different manufacturers (for example, Leica or Imetric) supply coded targets. These are generally self-adhesive and therefore cannot accurately be placed with respect to features of the workpiece such as datum holes.

Other types of target (such as "Hubbs" high quality targets which are made to high accuracy to enable them to be fitted precisely to features of the workpiece such as datum holes) are expensive due to the high accuracy required.

Furthermore, the coding schemes adopted by the different manufacturers are not compatible; the pattern recognition software supplied by a manufacturer will, in general, only recognise targets supplied by that manufacturer.

The use of coded targets for high precision measurement could therefore involve storing a large number of different targets, for each different size of datum hole in each different coding scheme.

According to a first aspect, the present invention resides in a set of photogrammetry targets comprising a first portion and a plurality of interchangeable second portions, wherein the first portion comprises a first connector for connection to a workpiece and wherein each of the plurality of interchangeable second portions carries a respective different visual identifier on an outer surface thereof and each comprises a second connector for connection to the first portion.

Optionally, the first connector comprises a stub for receiving within a recess or hole in the workpiece. This allows convenient and accurate mounting of the target to the workpiece. The first connector may comprise an adhesive region on a surface of the first portion that is contactable to the workpiece. This allows adhesion to the workpiece and hence provides an alternative method of mounting the target to the workpiece. Furthermore, whether used in conjunction with or as an alternative to the stub mounting, the adhesion allows more reliable positioning over time as the chances of movement, including rotation, of the target once positioned is reduced.

Preferably, the second connector comprises a snap-fit coupling thereby allowing quick convenient assembly of the first and second portions. Advantageously, the second portion comprises a hole through which passes. Conveniently, the part of the first portion may carry a retroreflector.

Optionally, the second connector comprises a surface for releasable connection to a surface of the first portion. This provides an alternative form of assembly of the first and second portions. Conveniently, the surface of the second connector comprises a tacky layer.

The invention also extends to a first portion or a second portion for use with a set as defined herein above.

From a second aspect, the present invention resides in a method of applying a photogrammetry target to a workpiece, comprising the steps of attaching a first target portion to the workpiece at a predetermined position thereon and attaching a second target portion carrying a visual identifier on a surface thereof to the first target portion. The order in which the steps of the method are carried out is not crucial, i.e. the first target portion may be attached to the workpiece prior to or subsequent to attaching the second target portion thereto.

Preferably, the method further comprises the step of selecting the second portion from a plurality of second portions carrying different visual identifiers.

The present invention also extends to a method of measuring a workpiece comprising the steps of successively applying a plurality of photogrammetry targets to the object according to the method described herein above and photogrammetrically measuring the positions of the targets. Furthermore, the present invention also extends to a method of working a workpiece, comprising the steps of measuring the workpiece as defined herein above and processing the workpiece at a point selected depending upon the measured position.

The invention will now be illustrated, by way of example only, with reference to the accompanying drawings in which:

Figure 1 illustrates schematically the components of a positioning system using photogrammetry;

Figure 2 illustrates schematically a known photogrammetry target;

Figure 3 (comprising Figures 3a-3c) illustrates known photogrammetry coding schemes;

Figure 4 illustrates schematically a first photogrammetry target according to a first embodiment of the present invention; and

Figure 5 schematically illustrates a second photogrammetry target according to a second embodiment of the present invention.

Referring to Figure 1, the photogrammetry system (located within a workshop of a factory, for example) comprises a pair (or more) of video cameras 6a, 6b at different locations, each having within its field of view a workpiece 24 (for example, a larger workpiece such as an aircraft wing, or a smaller workpiece such as a car panel). The video cameras 6a, 6b are connected via respective cables 7a, 7b to an analysis apparatus 5, which here comprises a programmed workstation such a Sun SparcStation™, comprising a processor, memory, storage (e.g. a hard disk), and video capture electronics.

A robot 21 carries a drill 23 (or other workpiece) under control of the analyser apparatus 5, to work on the workpiece 24.

The workpiece 24 carries a number of targets 3, and the robot 21 and tool 23 also carry respective targets 4, 22.

In operation, the apparatus detects the position of the workpiece 24 within the frame of reference of the workshop; detects the position of the robot 21 within the frame of reference of the workshop; then accesses a computer aided manufacturing (CAM) file to determine the points on the workpiece 24 to be processed (e.g. drilled); then causes the robot 21 to move to the tool 23 to the correct position on the workpiece 24 and perform the required operations.

Each of the targets 3, 4, 22 are differently coded (i.e. carry different codes on their visible surface). The analysis apparatus 5 is therefore able to determine the identity of each of the targets 3, 4, 22, so as to match corresponding targets 3, 4, 22 in the views seen by the two cameras 6a, 6b. Further, the codes on each target 3, 4, 22 allow each to be associated with a particular known point on the workpiece 24, the position (on the workpiece 24) of which are stored in the analysis apparatus 5.

It is therefore possible for the analysis apparatus 5 to derive, from the target positions, the positions of the corresponding parts of the workpiece 24; and hence to calculate the position and orientation of the workpiece 24 within the frame of reference of the workshop (or, to put it differently, to calculate the transformation between the frame of reference of the workpiece 24 itself and that of the workshop). The same is true of the position of the robot 21.

The present invention is not concerned with the details of the photogrammetry or metrology process, or of the computer aided manufacturing process, which may both be performed in conventional fashion using commercially available equipment.

Referring to Figure 2, a conventional coded target is shown, comprising an accurately machined stub or pin 30 for locating in a hole in a workpiece 24, carrying a plate 40 which has a number of visually distinctive marks on its outer surface.

Referring to Figure 3, Figure 3a shows the coding scheme used by Imetric, comprising a series of arcuate strips 41, 42, 43, of different lengths, and Figure 3b shows the coding scheme used by Leica comprising a series of squares 44, 45, 46 in different orientations. Each target of one of these types has a different code, formed by the presence or orientation of the strips shown in Figure 3a or 3b.

The analyser apparatus 5 operates software supplied by one of those companies which is specifically arranged to recognise the coded marks, to identify the different targets within the field of view of the cameras 6.

Referring now to Figure 4, the coded target set of a first embodiment of the invention will now be described. It comprises a first part consisting of an accurately machined stub 50, carrying a coaxial cylinder 52 having a retroreflector 54 on its outer end. These components may be provided by a "Hubbs" type target, available from Hubbs Industries. Next to the outer end of the cylinder 52 is a slightly recessed ring 55.

A second part comprises a flat plate 60 like the plate 40, formed of resilient plastics material, and carrying coded marks 61, 62, 63. Located centrally within the plate is a hole 65, dimensioned to be an interference fit on the cylinder 52 and to engage the recessed ring 55.

Thus, in use, the plate 60 can be removably snapped onto the cylinder 52 (either before mounting the stub 50 to the workpiece or afterwards), with an interference fit for high accuracy, leaving the retroreflector 54 visible. The position of the target is determined by the analysis apparatus 5 from the retroreflector 54, and its identity from the coded plate 60.

After measurements are taken, the plate 60 can be removed and interchanged with another, such as the plate 70 (having an identical hole 75, but different coded marks 71, 72, 73.

This embodiment therefore decouples the high-accuracy first part carrying the retroreflector, which is used for accurately gauging position, from the second part carrying the code, which requires only a lower accuracy. First parts can therefore be made with different stub diameters for a range of different hole sizes, but the same cylinder diameter so that any one can accept any of a number of different second parts.

Thus, whereas in the past it was necessary to carry a set of coded targets for each hole diameter, for each target manufacturer, and possibly also for different lenses and distances from the target, this embodiment allows a much smaller number of components (particularly high accuracy and hence expensive components) to achieve the same effect. It therefore also becomes possible to change cameras and analysis apparatus or programs (requiring different coded targets) without discarding the first (expensive) target parts, or re-mounting targets.

In this embodiment, rather than providing the coded marks directly printed onto the plate 60 or 70, the plate could receive a self adhesive paper ring carrying the coded marks, allowing even greater flexibility.

Referring to Figure 5, a second embodiment is shown in which the second parts are substantially as described in the first embodiment. However, the first part comprises a strip 80 carrying, on it's lower (inner) face, an adhesive layer to allow it to stick to the workpiece and, on its upper (outer) face, a retroreflector 84.

The second part 60 has, on its lower face, a tacky layer (e.g. of PVC) for releasable attachment to the upper (outer) face of the first part, leaving the retroreflector 84 visible through the hole 65 in the second part.

Thus, the first part can be left in place (with the retroreflector positioning target 84) whilst the coded second parts are replace in situ on the workpiece. This enables the use of different measurement systems from different manufacturers at different stages of the manufacturing process, for example to allow a high

resolution measurement system to be used in the tool room to calibrate the targets (i.e. to determine their position), whereas a low resolution system may be used to work with the targets in the workplace.

It will be apparent to the skilled person that various alternatives or modifications to the above-described embodiments could be employed, and all are to be considered as within the scope of the present invention.

For example, rather than multiple cameras, a single camera moved between several positions could be used. Rather than connecting by electronic cable, removable media could be used, in which the media (which could even be film-based) are removed from the cameras physically and the data they carry input to the computer.

Rather than snap-fit couplings (such as bayonet or spring-clips), accurately machined screw or other couplings could be used.

The invention could be used for measuring position, or orientation, or dimensions, independently of each other, or all three.

CLAIMS

1. A set of photogrammetry targets comprising a first portion and a plurality of interchangeable second portions, wherein the first portion comprises a first connector for connection to a workpiece and wherein each of the plurality of interchangeable second portions carries a respective different visual identifier on an outer surface thereof and each comprises a second connector for connection to the first portion.

2. A set according to claim 1, wherein the first connector comprises a stub for receiving within a recess or hole in the workpiece.

3. A set according to claim 1 or claim 2, wherein the first connector comprises an adhesive region on a surface of the first portion that is contactable with the workpiece.

4. A set according to any of claims 1 to 3, wherein the second connector comprises a snap-fit coupling.

5. A set according to claim 4, wherein the second portion comprises a hole through which part of the first portion passes.

6. A set according to claim 5, wherein the part of the first portion carries a retroreflector.

7. A set according to any of claims 1 to 6, wherein the second connector comprises a surface for releasable connection to a surface of the first portion.

8. A set according to claim 7, wherein the surface of the second connector comprises a tacky layer.

9. A first portion for use in a set according to any preceding claim.

10. A second portion for use in a set according to any preceding claim.

11. A method of applying a photogrammetry target to a workpiece, comprising the steps of attaching a first target portion to the workpiece at a predetermined position thereon and attaching a second target portion carrying a visual identifier on a surface thereof to the first target portion.

12. A method according to claim 11, further comprising the step of selecting the second portion from a plurality of second portions carrying different visual identifiers.

13. A method of measuring a workpiece comprising the steps of successively applying a plurality of photogrammetry targets to the object according to the method of claim 11 or claim 12 and photogrammetrically measuring the positions of the targets.

14. A method of working a workpiece, comprising the steps of measuring the workpiece according to claim 13 and processing the workpiece at a point selected depending upon the measured position.

15. A set of photogrammetry targets substantially as described hereinbefore with reference to Figures 4 or 5 of the accompanying drawings.

16. A method applying a photogrammetry target to a workpiece substantially as described hereinbefore with reference to Figures 4 or 5 of the accompanying drawings.

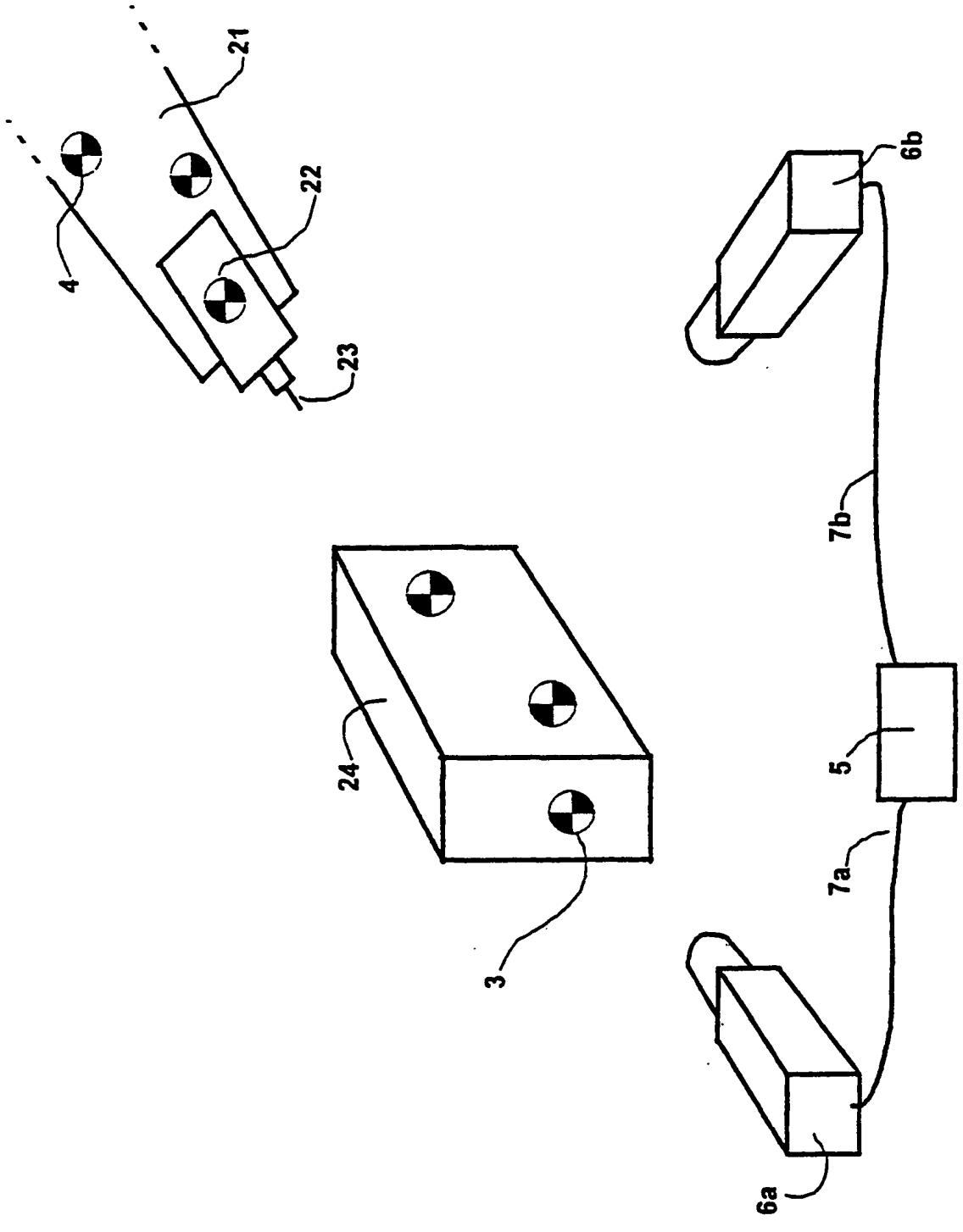

FIG. 1

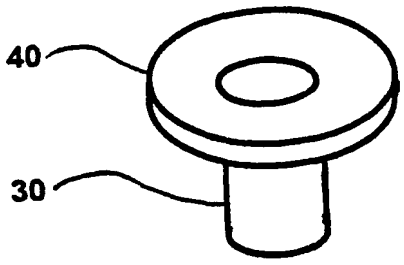

FIG. 2

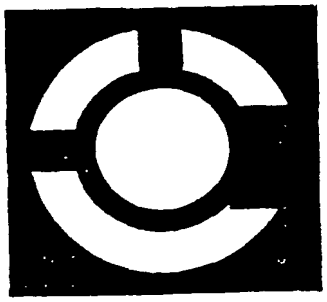

FIG. 3a

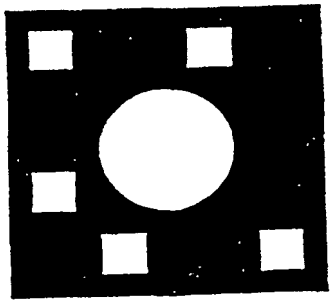

FIG. 3b

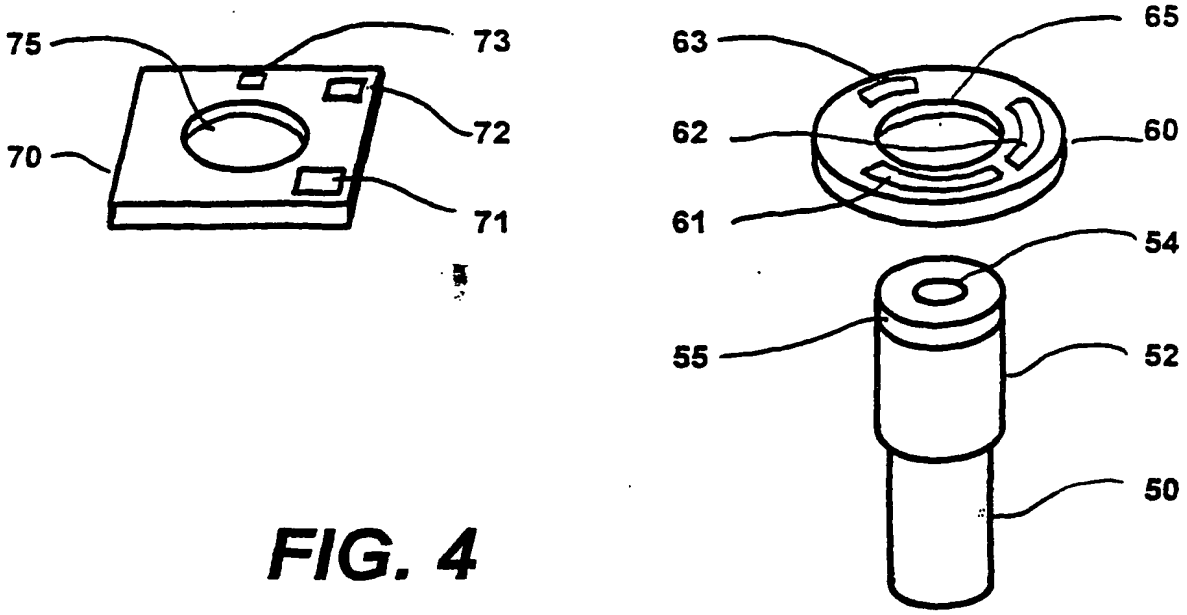

FIG. 4

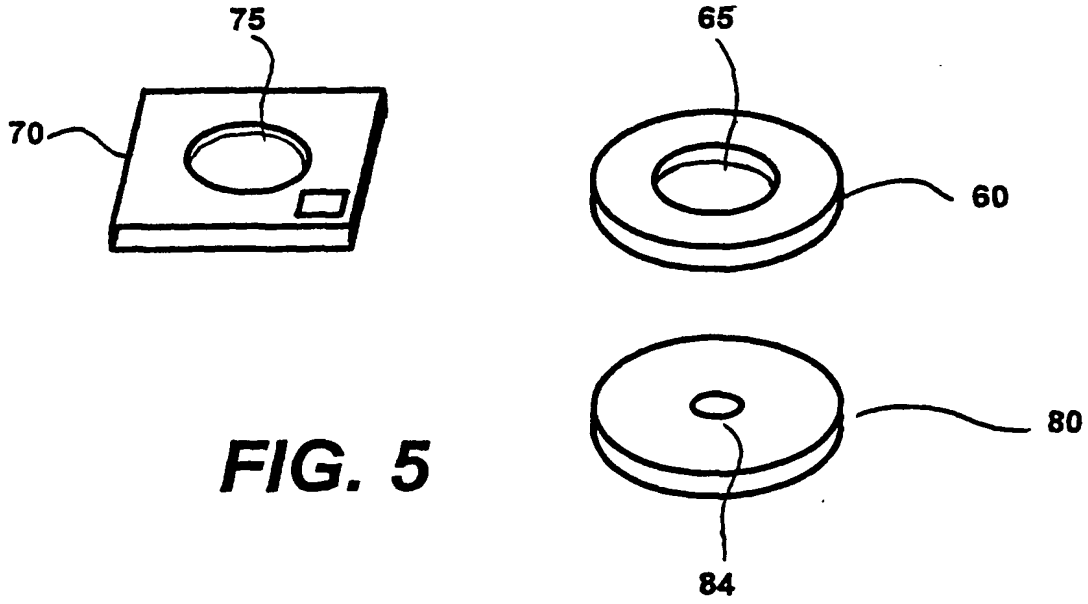

FIG. 5

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01B11/00 G01B21/04 G01C15/02 G02B5/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01B G02B G01C B25J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 801 834 A (WESTHOFF THOMAS M ET AL) 1 September 1998 (1998-09-01) column 4, line 46 -column 5, line 17; figure 1 column 7, line 14 -column 10, line 10; figures 5-12 column 14, line 31-55; figures 21-25	1-4,7-16
X	WO 01 04575 A (GOOCH RICHARD MICHAEL ;BAE SYSTEMS PLC (GB)) 18 January 2001 (2001-01-18) page 6, line 17 -page 7, line 11; figure 1	1,3,7-16
X	EP 1 091 186 A (PERCEPTION INC) 11 April 2001 (2001-04-11) column 5, line 51 -column 6, line 27; figure 3 column 8, line 7-27; figure 6	1,3,7-16

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search	Date of mailing of the international search report
22 July 2002	30/07/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Beyfuß, M

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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Form PCT/ISA/210 (continuation of second sheet) (July 1992)

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Information on patent family members

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